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(54) [Title of the Invention] LIGHTING DEVICE, UNIFORM LIGHTING DEVICE, AND PROJECTION DEVICE, LIGHT-EXPOSURE DEVICE AND LASER PROCESSING DEVICE USING THESE

(57) [Abstract]

[Object] To provide a lighting optical system with a compact structure, which uniformly irradiates an irradiation surface with beams emitted from multiple light sources, at a minimum incident angle with respect to the irradiation surface, and an optical device using this.

[Solution] In a laser array 11, laser light-emitting portions 11a, 11b, 11c... are linearly arranged at an equal pitch, and an outgoing beam B1 is made into a parallel beam flux (beam flux B2) with a cylindrical lens array 12 in at least one direction thereof. For example, in the example of FIG. 1, the outgoing beam B1 is made parallel in a direction parallel to the paper surface. Then, an outgoing beam flux B3 is converged into an incident-side edge surface 14a of a kaleidoscope 14 by a condenser lens 13. In the kaleidoscope 14, the in-plane intensity distribution of the beam flux is made uniform, and a relay lens 15 irradiates an irradiation portion 16 with the beam flux.

[Scope of Claims]

[Claim 1] A lighting device characterized by comprising: a light-emitting means having multiple light-emitting portions; a beam-parallelizing means for making a diffusive beam emitted from each light-emitting portion be parallel in at least one same direction of a surface that crosses the optical axis of the diffusive beam at right angles; and a condenser means for condensing multiple beam fluxes emitted from the beam-parallelizing means into a predetermined range of condensing.

[Claim 2] The lighting device according to claim 1, characterized in that the beam-parallelizing means is constructed of a lens that is fixed onto each light-emitting portion of the light-emitting means.

[Claim 3] The lighting device according to claim 1 or 2, characterized in that the light-emitting means is constructed of a laser light-emitting portion that emits laser beams.

[Claim 4] The lighting device according to any one of claims 1 to 3, characterized in that the light-emitting means is constructed in such a manner that the multiple light-emitting portions are arranged in an array in one direction; and the beam-parallelizing means is constructed in such a manner that beams emitted from the multiple light-emitting portions are made parallel in a

direction corresponding to the array arrangement direction.

[Claim 5] The lighting device according to claim 4, characterized in that a cylindrical lens array is used as the beam-parallelizing means; and each cylindrical lens portion that constitutes the cylindrical lens array has about an equal array pitch to the light-emitting portions.

[Claim 6] The lighting device according to claim 5, characterized in that at least two cylindrical lens arrays are provided.

[Claim 7] The lighting device according to claim 4, characterized in that a lenticular lens is used as the beam-parallelizing means; and each microlens that constitutes the lenticular lens has about an equal array pitch to the light-emitting portions.

[Claim 8] The lighting device according to claim 7, characterized in that at least two lenticular lenses are provided.

[Claim 9] A uniform lighting device, characterized by comprising the lighting device according to any one of claims 1 to 8; and an intensity distribution uniformizing means for receiving an irradiated beam emitted from the lighting device and uniformizing the beam intensity distribution on a surface that crosses the optical axis of the received beam at right angles, wherein the beam emitted from the intensity distribution uniformizing means is controlled to irradiate the irradiation object.

[Claim 10] The uniform lighting device according to claim 9, characterized by using a kaleidoscope as the intensity distribution uniformizing means.

[Claim 11] The uniform lighting device according to claim 9, characterized by using a homogenizer as the intensity distribution uniformizing means.

[Claim 12] The uniform lighting device according to claim 9, characterized by using a fly-eye lens as the intensity distribution uniformizing means.

[Claim 13] A lighting optical device comprising: a laser array where multiple laser light-emitting portions are arranged in an array; a cylindrical lens array where cylindrical lenses are arranged in an array in the array arrangement direction of the laser array at about an equal array pitch to the laser light-emitting portions; a kaleidoscope for uniformizing the intensity distribution of a beam flux emitted from the cylindrical lens; and a relay lens for irradiating the irradiation object by controlling the optical path of a beam emitted from the kaleidoscope, wherein the uniform lighting device is characterized in that: the cylindrical lens array operates on a diffusive beam

emitted from each laser light-emitting portion and is constructed in such a manner that the outgoing beam emitted from the cylindrical lens array is made parallel in the array direction of the cylindrical lens.

[Claim 14] A lighting optical device comprising: a laser array where multiple laser light-emitting portions are arranged in an array; a lenticular lens where microlenses are arranged in an array in the array arrangement direction of the laser array at about an equal array pitch to the laser light-emitting portions; a kaleidoscope for uniformizing the intensity distribution of a beam flux emitted from the lenticular lens; and a relay lens for irradiating the irradiation object by controlling the optical path of a beam emitted from the kaleidoscope, wherein the uniform lighting device is characterized in that: the lenticular lens operates on a diffusive beam emitted from each laser light-emitting portion and is constructed in such a manner that the outgoing beam emitted from the lenticular lens is made parallel in the array direction of the lenticular lens.

[Claim 15] A lighting optical device comprising: a laser array where multiple laser light-emitting portions are arranged in an array; a cylindrical lens array where cylindrical lenses are arranged in an array in the array arrangement direction of the laser array at about an equal array pitch to the laser light-emitting portions; a homogenizer for uniformizing the intensity distribution of a beam flux emitted from the cylindrical lens array; and a relay lens for irradiating the irradiation object by controlling the optical path of a beam emitted from the homogenizer, wherein the uniform lighting device is characterized in that: the cylindrical lens array operates on a diffusive beam emitted from each laser light-emitting portion and is constructed in such a manner that the outgoing beam emitted from the cylindrical lens array is made parallel in the array direction of the cylindrical lens array.

[Claim 16] A lighting optical device comprising: a laser array where multiple laser light-emitting portions are arranged in an array; a lenticular lens where microlenses are arranged in an array in the array arrangement direction of the laser array at about an equal array pitch to the laser light-emitting portions; a homogenizer for uniformizing the intensity distribution of a beam flux emitted from the lenticular lens; and a relay lens for irradiating the irradiation object by controlling the optical path of a beam emitted from the homogenizer, wherein the uniform lighting device is characterized in that the lenticular lens operates on a diffusive beam emitted from each laser light-emitting portion and is constructed in such a manner that the outgoing

beam emitted from the lenticular lens is made parallel in the array direction of the lenticular lens.

[Claim 17] A lighting optical device comprising: a laser array where multiple laser light-emitting portions are arranged in an array; a cylindrical lens array where cylindrical lenses are arranged in an array in the array arrangement direction of the laser array at about an equal array pitch to the laser light-emitting portions; and a fly-eye lens for uniformizing the intensity distribution of a beam flux emitted from the cylindrical lens array, with an outgoing beam of which, the irradiation object is irradiated, wherein the uniform lighting device is characterized in that the cylindrical lens array operates on a diffusive beam emitted from each laser light-emitting portion and is constructed in such a manner that the outgoing beam emitted from the cylindrical lens array is made parallel in the array direction of the cylindrical array lens.

[Claim 18] A lighting optical device comprising: a laser array where multiple laser light-emitting portions are arranged in an array; a lenticular lens where microlenses are arranged in an array in the array arrangement direction of the laser array at about an equal array pitch to the laser light-emitting portions; and a fly-eye lens for uniformizing the intensity distribution of a beam flux emitted from the lenticular lens, of which outgoing beam is controlled in optical path to irradiate the irradiation object, wherein the uniform lighting device is characterized in that the lenticular lens operates on a diffusive beam emitted from each laser light-emitting portion and is constructed in such a manner that the outgoing beam emitted from the lenticular lens is made parallel in the array direction of the lenticular lens.

[Claim 19] The uniform lighting device according to any one of claims 13, 15 and 17, characterized by comprising at least two cylindrical lens arrays.

[Claim 20] The uniform lighting device according to any one of claims 14, 16 and 18, characterized by comprising at least two lenticular lens arrays.

[Claim 21] A projection device characterized by comprising: at least the uniform lighting device according to any one of claims 9 to 20; a light bulb lighted by the uniform lighting device; and a projection lens for projecting the light emitted from the light bulb.

[Claim 22] A light-exposure device characterized by comprising: the uniform lighting device according to any one of claims 9 to 20 that uses a laser array as the light-emitting means; a reticle; and a projection lens.

[Claim 23] A laser processing device characterized by comprising: the uniform lighting device

according to any one of claims 9 to 20 that uses a laser array as the light-emitting means; and a condenser lens.

[Detailed Description of the Invention]

[0001]

[Industrial Field of the Invention] The present invention relates to a lighting optical device, a lighting optical system, and a projection device, a light-exposure device and a laser processing device using these. More particularly, the invention relates to a device capable of using multiple light-emitting sources of a laser array or the like as light sources and applying the light of the light sources to an optical system that uniformly irradiates an irradiation portion, the technique of which can be applied to a projection device (projector), a stepper (light-exposure device) and the like.

[0002]

[Prior Art] An optical system for uniformly irradiating an irradiation portion as an irradiation object is required to be suitable for, for example, a light-bulb type projection device using a liquid crystal display element, a stepper or the like used for manufacturing a semiconductor or the like, as well as being used for various applications. Thus, a high-precision optical system with a compact and simple structure is required. In the aforementioned light-bulb type projection device, for example, it is desired to set a lighting optical system in such a manner that a maximum incident angle with respect to the light bulb can be as small as possible (that is, an incident angle with respect to the surface of a light bulb can be as vertical as possible).

[0003]

[Problems to be Solved by the Invention] The invention is made in view of the foregoing circumstances, and it is an object of the invention to provide a lighting device that realizes a compact structure by using a light-emitting unit composed of multiple light sources in order to uniformly irradiate an irradiation surface with beams emitted from the multiple light sources, at a minimum incident angle with respect to the irradiation surface, and a projection device, a light-exposure device and a laser processing device using this.

[0004]

[Means for Solving the Problem] The invention according to claim 1 is characterized by having a light-emitting means having multiple light-emitting portions; a beam-parallelizing means for

making a diffusive beam emitted from each light-emitting portion be parallel in at least one same direction of a surface that crosses the optical axis of the diffusive beam at right angles; and a condenser means for condensing multiple beam fluxes emitted from the beam-parallelizing means into a predetermined range of condensing.

[0005] The invention according to claim 2 is characterized in that, in the invention according to claim 1, the beam-parallelizing means is constructed of a lens that is fixed onto each light-emitting portion of the light-emitting means.

[0006] The invention according to claim 3 is characterized in that, in the invention according to claim 1 or 2, the light-emitting means has a laser light-emitting portion that emits laser beams.

[0007] The invention according to claim 4 is characterized in that, in the invention according to any one of claims 1 to 3, the light-emitting means is constructed in such a manner that the multiple light-emitting portions are arranged in an array in one direction; and the beam-parallelizing means is constructed in such a manner that beams emitted from the multiple light-emitting portions are made parallel in a direction corresponding to the array arrangement direction.

[0008] The invention according to claim 5 is characterized in that, in the invention according to claim 4, a cylindrical lens array is used as the beam-parallelizing means; and each cylindrical lens portion that constitutes the cylindrical lens array has an equal array pitch to the light-emitting portions.

[0009] The invention according to claim 6 is characterized in that, in the invention according to claim 5, at least two cylindrical lens arrays are provided.

[0010] The invention according to claim 7 is characterized in that, in the invention according to claim 4, a lenticular lens is used as the beam-parallelizing means; and each microlens that constitutes the lenticular lens has about an equal array pitch to the light-emitting portions.

[0011] The invention according to claim 8 is characterized in that, in the invention according to claim 7, at least two lenticular lenses are provided.

[0012] The invention according to claim 9 is characterized by having the lighting device according to any one of claims 1 to 8, and an intensity distribution uniformizing means for receiving an irradiated beam emitted from the lighting device and uniformizing the beam intensity distribution on a surface that crosses the optical axis of the received beam at right

angles, where the light emitted from the intensity distribution uniformizing means is controlled to irradiate the irradiation object.

[0013] The invention according to claim 10 is characterized by using a kaleidoscope as the intensity distribution uniformizing means in the invention according to claim 9.

[0014] The invention according to claim 11 is characterized by using a homogenizer as the intensity distribution uniformizing means in the invention according to claim 9.

[0015] The invention according to claim 12 is characterized by using a fly-eye lens as the intensity distribution uniformizing means in the invention according to claim 9.

[0016] The invention according to claim 13 is a lighting optical device having a laser array where multiple laser light-emitting portions are arranged in an array; a cylindrical lens array where cylindrical lenses are arranged in an array in the array arrangement direction of the laser array at about an equal array pitch to the laser light-emitting portions; a kaleidoscope for uniformizing the intensity distribution of a beam flux emitted from the cylindrical lens; and a relay lens for irradiating the irradiation object by controlling an optical path of a beam emitted from the kaleidoscope, characterized in that the cylindrical lens array operates on a diffusive beam emitted from each laser light-emitting portion and is constructed in such a manner that the outgoing light emitted from the cylindrical lens array is made parallel in the array direction of the cylindrical lens.

[0017] The invention according to claim 14 is a lighting optical device having a laser array where multiple laser light-emitting portions are arranged in an array; a lenticular lens where microlenses are arranged in an array in the array arrangement direction of the laser array at about an equal array pitch to the laser light-emitting portions; a kaleidoscope for uniformizing the intensity distribution of a beam flux emitted from the lenticular lens; and a relay lens for irradiating the irradiation object by controlling the optical path of a beam emitted from the kaleidoscope, characterized in that the lenticular lens operates on a diffusive beam emitted from each laser light-emitting portion and is constructed in such a manner that the outgoing beam emitted from the lenticular lens is made parallel in the array direction of the lenticular lens.

[0018] The invention according to claim 15 is a lighting optical device having a laser array where multiple laser light-emitting portions are arranged in an array; a cylindrical lens array where cylindrical lenses are arranged in an array in the array arrangement direction of the laser

array at about an equal pitch to the laser light-emitting portions; a homogenizer for uniformizing the intensity distribution of a beam flux emitted from the cylindrical lens array; and a relay lens for irradiating the irradiation object by controlling the optical path of a beam emitted from the homogenizer, characterized in that the cylindrical lens array operates on a diffusive beam emitted from each laser light-emitting portion and is constructed in such a manner that the outgoing beam emitted from the cylindrical lens array is made parallel in the array direction of the cylindrical lens array.

[0019] The invention according to claim 16 is a lighting optical device having a laser array where multiple laser light-emitting portions are arranged in an array; a lenticular lens where microlenses are arranged in an array in the array arrangement direction of the laser array at about an equal array pitch to the laser light-emitting portions; a homogenizer for uniformizing the intensity distribution of a beam flux emitted from the lenticular lens; and a relay lens for irradiating the irradiation object by controlling the optical path of a beam emitted from the homogenizer, characterized in that the lenticular lens operates on a diffusive beam emitted from each laser light-emitting portion and is constructed in such a manner that the outgoing beam emitted from the lenticular lens is made parallel in the array direction of the lenticular lens.

[0020] The invention according to claim 17 is a lighting optical device having a laser array where multiple laser light-emitting portions are arranged in an array; a cylindrical lens array where cylindrical lenses are arranged in an array in the array arrangement direction of the laser array at about an equal array pitch to the laser light-emitting portions; and a fly-eye lens for uniformizing the intensity distribution of a beam flux emitted from the cylindrical lens array, with an outgoing beam of which, the irradiation object is irradiated, characterized in that: the cylindrical lens array operates on a diffusive beam emitted from each laser light-emitting portion and is constructed in such a manner that the outgoing beam emitted from the cylindrical lens array is made parallel in the array direction of the cylindrical lenticular lens.

[0021] The invention according to claim 18 is a lighting optical device having a laser array where multiple laser light-emitting portions are arranged in an array: a lenticular lens where microlenses are arranged in an array in the array arrangement direction of the laser array at about an equal array pitch to the laser light-emitting portions; and a fly-eye lens for uniformizing the intensity distribution of a beam flux emitted from the lenticular lens, of which outgoing beam is

controlled in optical path to irradiate the irradiation object, characterized in that the lenticular lens operates on a diffusive beam emitted from each laser light-emitting portion and is constructed in such a manner that the outgoing beam emitted from the lenticular lens is made parallel in the array direction of the lenticular lens.

[0022] The invention according to claim 19 is characterized in that, in the invention according to any one of claims 13, 15 and 17, at least two cylindrical lens arrays are provided.

[0023] The invention according to claim 20 is characterized in that, in the invention according to any one of claims 14, 16 and 18, at least two lenticular lens arrays are provided.

[0024] The invention according to claim 21 is characterized by having the invention according to any one of claims 9 to 20; a light bulb lighted by the uniform lighting device; and a projection lens for projecting the light emitted from the light bulb.

[0025] The invention according to claim 22 is characterized by having the uniform lighting device according to any one of claims 9 to 20 that uses a laser array as the light-emitting means; a reticle; and a projection lens.

[0026] The invention according to claim 23 is characterized by having the uniform lighting device according to any one of claims 9 to 20 that uses a laser array as the light-emitting means; and a condenser lens.

[0027]

[Embodiment Modes of the Invention] First, description is made below with reference to the drawings on an essential constitution of the invention. Note that constitutions of embodiments are individually described later in details with reference to the drawings again. A lighting device of the invention has a light-emitting means 11 having multiple light-emitting portions 11a, 11b and 11c, a beam-parallelizing means 12 for making a diffusive beam emitted from each of the light-emitting portions 11a, 11b and 11c be parallel in at least one same direction of a surface that crosses the optical axis of the diffusive beam at right angles, and a condenser means 13 ((31, 32, 33), (41), (51)) for condensing multiple beam fluxes that are emitted from the beam-parallelizing means 12 into a predetermined range of condensing. In the aforementioned lighting device, the beam-parallelizing means 12 may be constructed of a lens 12a that is fixed onto each light-emitting portion 11a of the light-emitting means as shown in FIG. 13. Alternatively, the aforementioned light-emitting means 11 can be constructed of the laser

light-emitting portions 11a, 11b, and 11c that emit laser beams.

[0028] In addition, the aforementioned light-emitting means is constructed in such a manner that the multiple light-emitting portions 11a, 11b and 11c are arranged in an array in one direction, while the beam-parallelizing means 12 is constructed in such a manner that outgoing beams from the multiple light-emitting portions are made parallel in a direction corresponding to the array arrangement direction. A cylindrical lens array is used as the aforementioned beam-parallelizing means 12, and each cylindrical lens that constitutes the cylindrical lens array is set to have an equal array pitch to the light-emitting portions. The number of such cylindrical lens array may be at least two.

[0029] In addition, a lenticular lens is used as the aforementioned beam-parallelizing means 11, and each microlens that constitutes the lenticular lens is set to have about an equal pitch to the light-emitting portions. The number of such lenticular lens may be at least two.

[0030] The uniform lighting device of the invention has the aforementioned lighting device, and an intensity distribution uniformizing means 14 ((42, 43), (52, 53)) for receiving an irradiated beam emitted from the lighting device and uniformizing the beam intensity distribution on a surface that crosses the optical axis of the received beam at right angles. The beam emitted from the intensity distribution means 14 is controlled to irradiate the irradiation object.

[0031] (Embodiment 1) FIG.1 and FIG. 2 are views for illustrating the first embodiment of the invention. FIG. 1 shows a top schematic structure of a lighting optical system and FIG. 2 shows a lateral schematic structure thereof along with optical paths. In FIG. 1 and FIG. 2, reference numeral 11 is a laser array, 12 is a cylindrical lens array, 13 is a condenser lens, 14 is a kaleidoscope, 15 is a relay lens, and 16 is an irradiation portion. In the laser array 11, the laser light-emitting portions 11a, 11b, 11c... are linearly arranged at an equal pitch. Each laser light-emitting portion emits each outgoing beam B1 as a diffusive beam. Such outgoing beam B1 is made into parallel beam flux with the cylindrical lens array 12 in one direction thereof. In the example of FIG. 1, the cylindrical lens array 12 outputs an incident beam flux as a beam flux B2 that has been made parallel in a direction parallel with the paper surface. The parallel beam flux B2 in this case is not required to be parallel in the strict sense unless adjacent beam fluxes cross each other with a large angular difference in the next condenser lens 13. That is, there is no problem even if the outgoing beam fluxes B2 overlap each other with a small angular

difference.

[0032] The condenser lens 13 converges an outgoing beam flux B3 into an incident-side edge surface 14a of the kaleidoscope 14. The beam flux traveling inside the kaleidoscope 14 is multi-reflected in the kaleidoscope 14, and the in-plane intensity distribution of the beam flux is uniformized in an outgoing edge-surface 14b. The beam flux having such uniformized intensity distribution is emitted onto the irradiation portion 16 by the relay lens 15.

[0033] The cylindrical lens array 12 may be replaced by a so-called lenticular lens. The cylindrical lens array 12 may be a lens array having about an equal array pitch to the laser array 11 and have lens power with respect to the arrangement direction of the laser array. In the case of using a lenticular lens also, each microlens is constructed to have about an equal array pitch to the laser array 11 and operate similarly. By disposing the cylindrical lens array 12 (or lenticular lens) on the optical path right after the laser array 11, the allowable setting range thereof in the thickness direction of the paper surface can be widened in FIG. 1 as compared to the case where the cylindrical lens array 11 is replaced by the linearly arranged lens array (having two-dimensional power), for example. That is, only fine adjustment in the up-and-down direction in FIG. 1 is required.

[0034] Description is made with reference to a beam trace calculation result for demonstrating that the maximum incident angle with respect to the irradiation portion 16 can be decreased by using the cylindrical lens array (or lenticular lens) 12. FIG. 3 is a view for illustrating an effect of a lighting optical system using a lenticular lens. FIG. 3(A) shows a schematic structure of a lighting optical system, and FIG. 3(B) shows a magnified view of a portion B in FIG. 3(A).

[0035] In the structure shown in FIG. 3, the laser array including the light sources 11a and 11c are actually arranged as shown in FIG. 1; however, illustration of the whole laser array 11 is omitted in order to illustrate a characteristic optical path. That is, the light source 11a shown in the drawing is positioned at an end portion of the laser array, a light source 11n is positioned at the center of the laser array 11, and other light sources that constitute the laser array are not illustrated. The cylindrical lens array (or lenticular lens) 12 is disposed right after the laser light source 11a. In FIG. 3(B), reference numeral 12a is one lens portion (cylindrical lens) that constitutes the cylindrical lens array 12, which is arranged in an array in a y direction similarly to the light sources 11a to 11n.

[0036] The array pitch of the light sources of the laser array 11 is equal to the array pitch of each lens of the cylindrical lens array 12 (or the array pitch of each microlens of the lenticular lens). In FIG. 3(B), only one microlens 12a that constitutes the lenticular portion (lenticular lens) corresponding to the light source 11a is shown. In the lenticular lens 12, a beam emitted from each laser array is made parallel in a direction parallel with the paper surface. In this lenticular lens 12, the outgoing light is not completely collimated due to the spherical aberration of the lens; however, such effect can be sufficiently obtained with a certain degree of parallel condensing. The beam B2 that has been made into a parallel beam flux passes through cylindrical lenses 21, 22 and 23 to reach the incident-side edge surface 14a of the kaleidoscope 14. In this case, a maximum incident angle with respect to the incident-side edge surface 14a is 12º.

[0037] The cylindrical lens 21 functions to deflect laser array beams toward the incident-side edge surface 14a of the kaleidoscope 14. The cylindrical lenses 22 and 23 function to converge diffusive beams in the thickness direction of the laser array (thickness direction of the paper surface) into the incident-side edge surface 14a.

[0038] (Comparative Example) FIG. 4 is a view for illustrating an operation in an optical system where the lenticular lens 12 is not provided in the structure of FIG. 3. FIG. 4 shows beams in the case where the cylindrical lens array 12 right after the light source 11a that is positioned at an end portion of the laser array is omitted in the optical system of FIG. 3. The diffusive beam B1 from the light source 11a passes through the cylindrical lenses 21, 22 and 23 and is emitted to the incident-side edge surface 14a of the kaleidoscope 14 at a maximum incident angle of 16º. An outgoing beam from the outgoing-side edge surface (not shown) of the kaleidoscope 14 is maintained at the incident angle; therefore, the beam is emitted at a maximum angle of 16º. Further, when comparing FIG. 4 and FIG. 3, the bore diameter of the kaleidoscope 14 can be made smaller in the case of using the cylindrical lens array 12. When comparing kaleidoscopes having the same number of reflections, the overall length becomes shorter as the bore diameter is smaller. Thus, the lighting optical system can be downsized by using the cylindrical lens array (or lenticular lens).

[0039] (Embodiment 2) FIG. 5 and FIG. 6 are views for illustrating the second embodiment of the invention. FIG. 5 shows a top schematic structure of a lighting optical system and FIG. 6

shows a lateral schematic structure thereof along with optical paths. The lighting optical system is composed of the lens array 11, the cylindrical lens array 12, the kaleidoscope 14, the relay lens 15, and cylindrical lenses 31, 32 and 33. Reference numeral 16 is an irradiation portion. Note that the cylindrical lens array 12 may be replaced by a lenticular lens as in Embodiment 1. At this time, the array direction of microlenses of the lenticular lens and the array pitch thereof are set similarly to the array structure of the cylindrical lens so that both of them function similarly. In this embodiment, description is made on an embodiment using the cylindrical lens array 12.

[0040] In the cylindrical lens array 12, a cylindrical surface is formed at an equal pitch to the array pitch of the laser array 11, and has lens power in the array direction of the laser array 11 as shown in FIG. 5. The cylindrical lens array 12 makes each laser array beam B1 that has been diffused and emitted into a parallel beam flux only in each array direction. The parallel beam flux B2 obtained in such a case is not required to be parallel in the strict sense. That is, there is no problem even if the beam flux overlaps each other with a small angular difference unless the adjacent beam fluxes cross each other with a large angular difference in the next cylindrical lens 31.

[0041] On the optical path between the cylindrical lens array 12 and the kaleidoscope 14, at least two cylindrical lenses are disposed. FIG. 5 and FIG. 6 each show an example of using three cylindrical lenses (the cylindrical lenses 31, 32 and 33). In this case, one cylindrical lens 32 having power in the array direction of the laser array 11 and two cylindrical lenses 31 and 33 having lens power in the vertical direction to the array direction of the laser array are disposed.

[0042] Description is made on the operation of such cylindrical lenses 31, 32 and 33. First, as shown in FIG. 5, in regard to a beam flux in the array direction of the laser array 11, the beam B2 that has been made into a parallel beam flux only in the array direction passes through the cylindrical lens 31 directly, thereby entering the cylindrical lens 32 as a beam flux B21 since the cylindrical lenses 31 and 33 can be regarded as identical to parallel plane plates. Then, the incident beam flux B21 is deflected by the cylindrical lens 32 (beam flux 22) and then passes through the cylindrical lens 33 (beam flux B23) to reach the incident-side edge surface 14a of the kaleidoscope 14.

[0043] Then, as shown in FIG. 6, in regard to a beam in the vertical direction to the array

direction of the laser array 11, the beam flux B1 that has been diffused by each laser light-emitting portion is further diffused even after having passed through the cylindrical lens array 12 to become the beam flux B2 since the cylindrical lens array 12 can be regarded as a parallel plate. Then, the beam flux B2 is made parallel with the cylindrical lens 31 (beam flux B21), which passes through the cylindrical lens 32 (beam flux B22) and converged into the kaleidoscope 14 by the cylindrical lens 33 (beam flux B23). The beam fluxes B21 and B22 are not required to be parallel beam fluxes in the up-and-down direction in FIG. 6 (that is, the vertical direction to the array direction of the laser array). Thus, the effect of the invention is not affected even if the cylindrical lenses 31 and 33 are replaced by one cylindrical lens for convergence into the kaleidoscope with the one lens.

[0044] (Embodiment 3) FIG. 7 and FIG. 8 are views illustrating the third embodiment of the invention. FIG. 7 shows a top schematic structure of a lighting optical system, and FIG. 8 shows a lateral schematic structure thereof along with optical paths. The lighting optical system is composed of the laser array 11, the cylindrical lens array (or lenticular lens) 12, a cylindrical lens 41, homogenizers 42 and 43, and cylindrical lenses 44 and 45. FIG. 16 shows a top view showing a structure of a laser beam irradiating device disclosed in Japanese Patent Laid-Open No. H09-234579 (FIG. 16(A)) and a lateral view thereof (FIG. 16(B)), which is a device for irradiating an irradiation portion with a linear beam with increased uniformity. In this embodiment, homogenizers 40a and 40b that are used in this optical system are utilized so that a rectangular irradiation portion is uniformly irradiated with a laser array beam.

[0045] The operation of the cylindrical lens array 12 (or lenticular lens which can substitute for this) is as described above; therefore, description thereon is omitted. The cylindrical lens 41 makes a diffusive beam component in the vertical direction to the array direction of the laser array 11 into a parallel beam flux (beam flux B31). The homogenizer 42 uniformizes a beam flux in the array direction of the laser array 11. Although the homogenizer 42 in this embodiment has a five-division structure, a beam flux can be made more uniform with a larger number of divisions. Note that the effect of a homogenizer cannot be obtained in the case where the beam incident on each lens array of the homogenizer 42 in FIG. 7 has the same intensity distribution. For example, when the array pitches of the lenticular lens 12 and the homogenizer 42 have a relation of integral multiples, such a phenomenon is caused. Beams

from the homogenizer 42 (beam fluxes B32 and B33) are condensed into the irradiation portion 16 by the cylindrical lens 44 (beam flux B34).

[0046] Meanwhile, as for the beam flux in the vertical direction to the array direction of the laser array 11, the intensity distribution of the beam flux is made uniform by the homogenizer 43 as shown in FIG.8. That is, a diffusive beam component that is incident on the cylindrical lens 41 is made into a parallel beam flux (beam flux B31), and the beam flux is divided by the homogenizer 43. Each of the divided beam fluxes is condensed and focused, and then becomes a diffusive beam (beam flux B33) to be overlapped on the irradiation portion 16 by the cylindrical lens 45 (beam flux B34). The homogenizer 43 that controls a beam flux in the vertical direction to the array direction of the laser array 11 has a higher effect with a large number of divisions.

[0047] By disposing the cylindrical lens array (lenticular lens) 12 right after the laser array 11, each array beam in the array direction can be made into a parallel beam flux as well as the effect of a homogenizer can be obtained. In addition, since the cylindrical lens array (or lenticular lens) is used, there is such an advantage that the setting accuracy is not required in the vertical direction to the array direction of the laser array.

[0048] (Embodiment 4) FIG. 9 and FIG. 10 are views for illustrating the fourth embodiment of the invention. FIG. 9 shows a top schematic structure of a lighting optical system, and FIG. 10 shows a lateral schematic structure thereof along with optical paths. The lighting optical system is composed of the laser array 11, the cylindrical lens array (or lenticular lens) 12, a cylindrical lens 51, fly-eye lenses 52 and 53, and a condenser lens 54. Although two fly-eye lenses 52 and 53 are used in this embodiment shown in the drawings, the second fly-eye lens 53 is not necessary required, and can thus be omitted. In addition, the condenser lens 54 can be replaced by two cylindrical lenses of which lens power directions are made to cross each other at right angles. Note that in this embodiment also, the cylindrical lens array can be replaced by a lenticular lens having a similar function as in each of the aforementioned embodiments.

[0049] First, description is made with reference to FIG. 9 on the operation of a beam component in the array direction. The cylindrical lens array 12 has about an equal array pitch to the laser array 11. The operation thereof is as described above. A beam in the array direction of the laser array is made into a substantially parallel beam flux B2 with the cylindrical lens array 12,

and then passes through the cylindrical lens 51 (beam flux B 41). Each beam flux emitted from the array light source is condensed by the first fly-eye lens 52 (beam flux B42). The second fly-eye lens 53 is disposed in the focus position of the first fly-eye lens 52. The second fly-eye lens 53 is not required if the traveling direction of a beam that has passed through the cylindrical lens array 12 in the paper surface of FIG. 9 is parallel with the axis of the first fly-eye lens 52. In addition, in the case where the beam flux B1 emitted from the laser array 11 cannot be regarded as a beam flux emitted from a point light source, in the case where the lens array 12 causes an aberration, or in the case where the pitches of the cylindrical lens 12 and the laser array 11 are misaligned, the beam flux B41 is slightly inclined relative to the first fly-eye lens 52. In such a case, beams condensed from each lens portion that constitutes the first fly-eye lens 52 are not gathered into one point; therefore, the second fly-eye lens 53 is required. The beam flux emitted from the second fly-eye lens 53 is overlapped with the irradiation portion 16 by the condenser lens 54 (beam flux B 43).

[0050] Next, description is made with reference to FIG. 10 on the operation regarding a beam flux component in the vertical direction to the array direction of the laser array. The outgoing beam flux B1 emitted from the laser array 11 passes through the cylindrical lens array 12 to become the beam flux B2, and then made into the parallel beam flux B41 with the cylindrical lens 51. As described above, the second fly-eye lens 53 is disposed in the focus distance position of the first fly-eye lens 52, and the beam flux emitted from each lens portion of the first fly-eye lens 52 (beam flux B42) passes through each lens portion of the second fly-eye lens 53, thereby the beam flux is overlapped with the irradiation portion 16 by the condenser lens 54 so that the irradiation portion 16 is uniformly irradiated (beam flux B43).

[0051] In the case where the thickness of the light-emitting portion of the laser array 11 (thickness in the array direction and the vertical direction) is large, the beam flux B41 is not necessarily parallel with the optical axis of the first fly-eye lens 52, and beams condensed from each array is not gathered into one point. Therefore, the second fly-eye lens 53 is used. If the aforementioned thickness of the light-emitting portion of the laser array can be regarded as sufficiently small, the beam flux emitted from each lens portion of the first fly-eye lens 52 (beam flux B42) is condensed into about one point; therefore, the second fly-eye lens 53 is not required. By using the cylindrical lens array 12, such an advantage can be provided that the allowable

setting range in the aforementioned thickness direction of the laser array 11 can be widened.

[0052] (Embodiment 5) FIG. 11 is a view showing a schematic structure of one embodiment of a projection device in accordance with the invention along with optical paths. The projection device is provided with the lighting optical system in accordance with any one of the aforementioned Embodiment 1 to Embodiment 4, a light bulb, and a projection lens. The projection device with the structure example shown in FIG. 11 is composed of lighting optical systems 61r, 61g and 61b, and a color composing element 62, a light bulb 65, and a projection lens 64. Although the optical system in Embodiment 3 is used as the lighting optical systems 61r, 61g and 61b in the structure shown in FIG. 11, any of the optical systems in Embodiment 1 to Embodiment 4 can be used as the lighting optical systems as described above.

[0053] As the color composing element 62, for example, a dichroic prism can be used. In the case where the lighting optical systems 61r, 61g and 61b are laser array light sources of a red color, green color and blue color in this order, the color composing element (dichroic prism) 62 is constructed in such a manner that a dichroic film 62r reflects a red color, a dichroic film 62b reflects a blue color, and both the dichroic films 62r and 62b transmit a green color. As the light bulb 65, for example, a liquid crystal element can be used. In the structure of FIG. 11, a field lens 63 is used right before the light bulb, which functions to transmit the light having passed through the light bulb 65 through an eye of the projection lens 64.

[0054] With the aforementioned structure, a maximum incident angle of a beam for lighting the light bulb 65 is decreased as compared to the conventional one; therefore, in the case of a light bulb of which contrast ratio changes in accordance with the incident angle such as a liquid crystal element, in particular, the contrast ratio can be increased while the color unevenness and luminance unevenness can be reduced.

[0055] Although FIG. 11 shows a structure example of using a single-plate light bulb, a total of three light bulbs 65r, 65g and 65b corresponding to the respective lighting optical systems 61r, 61g and 61b may be used as shown in FIG. 12. Disposed right before the respective light bulbs 65r, 65g and 65b are field lenses 63r, 63g and 63b. In the structure of FIG. 12, the optical path length between the projection lens 64 and the light bulbs 65r, 65g and 65b is long as compared to the structure of FIG. 11; therefore, the back focus length of the projection lens 64 is required to be longer than the back focus of the projection lens 64 in FIG. 11. In the projection device with

the light bulbs of three plates also, the contrast ratio can be improved as well as the color unevenness and luminance unevenness can be reduced similarly to the case of a single plate.

[0056] FIG. 14 is a view for illustrating a structure of a light-exposure device in accordance with the invention. In the drawing, reference numeral 71 is a uniform lighting device corresponding to any one of claims 9 to 20, 72 is a reticle, 73 is a projection lens, and 74 is a substrate stage. In the light-exposure device of the invention, the reticle 72 is lighted by the uniform lighting optical device 71 described in any one of claims 9 to 20, and a pattern of the reticle 72 is light-exposed onto a wafer set on the substrate stage 74 by the projection lens 73.

[0057] FIG. 15 is a view for illustrating a structure of a laser processing device in accordance with the invention. In the drawing, reference numeral 75 is a lens and 76 is a work. In the laser processing device in accordance with the invention, light emitted by the uniform lighting optical device according to any one of claims 9 to 20 is condensed into the work 76 with the lens 75, and thus processed. A condensed spot shape on the work 76 has an equal aspect ratio to the irradiation portion of the optical system 71. By condensing light, energy can be focused onto a minute portion of the work, and thus the surface processing, cutting or the like can be carried out. In addition, in the arrangement where the lens 75 is replaced by a projection lens or the irradiation potion corresponds directly to the work 76, a wide range can be irradiated uniformly; therefore, it can be used for laser annealing as well.

[0058]

[Effect] As is clear from the aforementioned description, in accordance with the lighting device of the invention, by realizing a compact optical system with multiple light sources and by condensing light by making a diffusive beam from the light sources into a parallel beam flux, a maximum incident angle with respect to the irradiation object can be suppressed small, thereby an optical system with favorable characteristics can be provided even when it is used for various applications.

[0059] In addition, in accordance with the uniform lighting device of the invention, by providing the aforementioned lighting device and a means for uniformizing the beam intensity distribution, a compact lighting device capable of uniform irradiation can be provided easily.

[0060]Further, by using the aforementioned lighting device capable of uniform irradiation, a projection device, a light-exposure device, a laser processing device or the like that is high

quality and compact can be provided. For example, in the projection device, the maximum incident angle with respect to the light bulb can be decreased; therefore, the characteristics regarding the contrast ratio, color unevenness and luminance unevenness can be improved.

[Brief Description of the Drawings]

[FIG. 1] a view for illustrating the first embodiment of the invention, which shows a top schematic structure of a lighting optical system.

[FIG. 2] a view for illustrating the first embodiment of the invention, which shows a lateral schematic structure of a lighting optical system.

[FIG. 3] a view for illustrating an effect of a lighting optical system using a lenticular lens.

[FIG. 4] a view for illustrating an operation in an optical system in the case of providing no lenticular lens in the structure of FIG. 3.

[FIG. 5] a view for illustrating the second embodiment of the invention, which shows a top schematic structure of a lighting optical system.

[FIG. 6] a view for illustrating the second embodiment of the invention, which shows a lateral schematic structure of a lighting optical system.

[FIG. 7] a view for illustrating the third embodiment of the invention, which shows a top schematic structure of a lighting optical system.

[FIG. 8] a view for illustrating the third embodiment of the invention, which shows a lateral schematic structure of a lighting optical system.

[FIG. 9] a view for illustrating the fourth embodiment of the invention, which shows a top schematic structure of a lighting optical system.

[FIG. 10] a view for illustrating the fourth embodiment of the invention, which shows a lateral schematic structure of a lighting optical system.

[FIG. 11] a view showing a schematic structure of a one embodiment of a projection device in accordance with the invention along with optical paths.

[FIG. 12] a view showing a schematic structure of a light source and a beam-parallelizing means in another embodiment of the lighting device of the invention along with optical paths.

[FIG. 13] a view showing a structure example of a light-emitting means and a beam-parallelizing means of the invention.

[FIG. 14] a view showing a homogenizer of prior art.

[FIG. 15] a view for illustrating a structure of a laser processing device in accordance with the invention.

[FIG. 16] a view showing a schematic structure of another embodiment of a projection device in accordance with the invention along with optical paths.

[Explanation of Reference]

11 ... laser array; 12 ... cylindrical lens array; 13 ... condenser lens; 14 ... kaleidoscope; 15 ... relay lens; 16 ... irradiation potion; 31, 32, 33, 41, 44, 45, 51 ... cylindrical lens; 40a, 40b ... homogenizer; 42, 43 ... homogenizer; 52, 53 ... fly-eye lens; 54 ... condenser lens; 61r, 61g, 61b ... lighting optical system; 62 ... color composing element; 62r, 62b ... dichroic film; 63, 63r, 63g, 63b ... field lens; 64 ... projection lens; 65, 65r, 65g, 65b ... light bulb; 71 ... uniform lighting device; 72 ... reticle, 73 ... projection lens; 74 ... substrate stage; 75 ... lens; and 76 ... work.